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United States Department of the Interior

U.S. GEOLOGICAL SURVEY
Office of the Director
Reston, Virginia 20192

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Mr. Robert G. Card, Under Secretary
Energy, Science and Environment
U.S. Department of Energy
1000 Independence Avenue, S.W.
Washington, D.C. 20585-0001

Dear Mr. Card:

This letter summarizes the position of the U.S. Geological Survey (USGS) relative to the current state of scientific knowledge about the Yucca Mountain site to help the Secretary of Energy decide whether to recommend the site for development as a spent nuclear fuel and high-level radioactive waste repository. The USGS is commenting within the scope of our Earth science expertise and is neutral regarding other information the Secretary may consider.

Earth scientists, many from the USGS, have long played an active role in studying the challenge of nuclear waste disposal. The conclusion drawn from these studies is that geologic disposal remains the only long-term approach for dealing with long-lived radioactive waste. Further, the USGS believes that the scientific work performed to date supports a decision to recommend Yucca Mountain for development as a nuclear waste repository. This position is based upon our understanding of the inherent natural attributes of the site as determined through extensive studies and takes into account the ability of the site to support waste retrieval long into the future. In addition to the positive attributes of the site, there is no feature or characteristic of the site that would preclude recommending the site. However, even after site recommendation, additional studies need to be performed, and there are some specific aspects of the proposed design that the USGS believes should be part of any final design.

Physical assets of the site include its relatively uncomplicated geology; the lack of economic mineral or energy deposits; the ease of excavating stable tunnels; the arid climate; the very low rate of infiltration of precipitation into the subsurface; the small percentage of infiltrating water that could actually seep into subsurface drifts (tunnels); and the free drainage, through fractures on the floor of the drifts, of any water that enters the tunnels. Additional positive attributes are the natural, passive ventilation of the mountain; the presence of an extremely thick unsaturated zone allowing the repository to be built far below the land surface and above the water table; and natural minerals known as zeolites which tend to retard the movement of certain radionuclides.

The Yucca Mountain site also has some characteristics that potentially may degrade repository performance and that consequently deserve scrutiny. If the President eventually designates Yucca Mountain, these attributes may require additional study and monitoring. During the preclosure period, critical surface facilities must be designed using state-of-the-art engineering practice to accommodate the potential for earthquakes. Whereas the engineering design is outside the scope of USGS studies, the USGS has confidence in the probabilistic earthquake hazard analyses upon which designs will be based. The potential for future volcanic activity has been extensively studied because of the presence of nearby volcanic features that are much younger than Yucca Mountain. The USGS concurs with expert panels that the probability of a repository-piercing eruption, including surface eruptions, is very low (on the order of 1.6×10^{-8}/year, or odds of 16 in a billion per year). However, other scientists believe that the probability may be perhaps ten times higher. Although this topic continues to be discussed, the total range of current probability estimates remains very low. Potential contamination of a deep, potable aquifer beneath the site is of concern because it is a valuable resource for the human and natural environment of this arid region. However, the USGS believes that the site characteristics of an arid climate coupled with the hydrologic characteristics of the thick unsaturated zone will result in very limited contact of water and waste. Future climate change is inherently uncertain and can result in positive or negative effects on the proposed repository. Plausible limits on the future climate are based on records of climate change over the past one million years. Expected states range from present, arid conditions to significantly cooler periods with double today's precipitation. It is likely that climate at Yucca Mountain in the next 10,000 years will be intermediate between the two extremes, that is, semi-arid. Finally, although the local geology of Yucca Mountain is relatively uncomplicated, the regional hydrologic system is complicated, particularly when future conditions are included. This complexity accounts in part for the unparalleled characterization effort expended at Yucca Mountain.

The discussion above is based upon the extensive studies conducted at Yucca Mountain. Nonetheless, it is practical and desirable to continue efforts to improve knowledge of the site, to reduce uncertainty, to apply new Earth science concepts as they develop, and to gather data to support refinements in repository plans.

As the final design of the repository is prepared, the USGS strongly supports the inclusion of three design considerations. First, maintaining the surrounding rock at a temperature less than boiling at all times will minimize potentially negative effects of the repository on the site's natural attributes and thereby lower uncertainty in its predicted performance. Second, forced and natural ventilation should be used to improve repository performance by lowering temperature and removing substantial amounts of moisture from the mountain. Third, a period of retrievability and monitoring preserves the options of future generations to make alternative disposal choices.

Evaluation of any alternative for nuclear waste disposal is limited by our ability to make long-term predictions. The Department of Energy is proposing recommending the Yucca Mountain site in part because the results of the Total System Performance Assessment (TSPA) indicate that

the amounts of radioactivity likely to be released from Yucca Mountain meet regulatory limits. The USGS recognizes the benefits of the TSPA modeling technique as an important evaluation tool, but the limits of quantitative prediction as embodied in the TSPA over such long time periods need to be recognized. This fact reinforces the importance of retrievability and monitoring as discussed above.

Additional confidence in the site's long-term ability to isolate waste from the biosphere can be attained through the examination of natural analogues and through geochemical studies. Studies of archeological and geological sites provide analogues for the potential of Yucca Mountain to isolate waste. Preservation of extremely fragile natural and human-made items for thousands to tens of thousands of years in caves, rock shelters, and fissures shows the potential to design and operate a repository successfully in the deep unsaturated zone of Yucca Mountain. Geochemical studies of calcite and opal in Yucca Mountain have shown unequivocal evidence that the water table has been below the proposed repository level for millions of years and that the effects of past climatic shifts are greatly attenuated at the proposed repository depth.

Recognizing that uncertainty in the future performance of the repository remains, the USGS endorses a stepwise decisionmaking process and phased implementation of the repository program. This approach allows for future decision-makers to select alternative options, if necessary, based upon additional information, different societal needs, or changing priorities.

A more detailed discussion of the above topics is attached to this letter. Please let me know if I can provide additional information.

Sincerely,

Charles G. Groat
Director

Enclosure

Copy To: Lake H. Barrett
J. Russell Dyer
Carol Hanlon

I. INTRODUCTION AND PURPOSE

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The Secretary of Energy is considering the Yucca Mountain site for recommendation as a spent nuclear fuel and high-level radioactive waste repository. The Secretary's decision is based, in part, on the geologic and hydrologic nature of the site as determined through site characterization activities. The U.S. Geological Survey (USGS) has no regulatory or management mandates and provides impartial science that serves the needs of the Nation. It is appropriate, therefore, for the Director of the USGS to provide policy-relevant, yet policy-neutral, science-based, input to the Secretary of Energy to aid in his decision.

II. GEOLOGIC DISPOSAL CONCEPT

Earth scientists, many from the USGS, have long played an active role in the examination of the problem of high-level radioactive waste disposal. Since the 1970s, USGS researchers have published studies of the concept of geologic disposal. In 1978, for example, the USGS considered different rock types, the effect of the waste on the rocks, movement of contaminants through ground water, and containment of waste in a philosophical discussion of the problem. Subsequently, the USGS studied different potential repository rocks, proposed the concept of a repository above the water table in arid regions, and investigated the hydrology and geology of Yucca Mountain.

National panels (such as the National Academy of Sciences/National Research Council) and international groups (for example, the Nuclear Energy Agency) examined the concept of geologic disposal of long-lived radioactive wastes on a number of occasions. These panels have consistently endorsed geologic disposal as the only viable long-term solution to the problem of long-lived radioactive waste. Considering the state of knowledge today, the USGS is confident that acceptable geologic repositories can be constructed. However, it is important that a repository be developed in a stepwise manner, with wastes remaining retrievable for a substantial period, in order to confirm the geologic and hydrologic attributes of the site or permit the development of alternative solutions by future generations.

III. THE YUCCA MOUNTAIN SITE

A. Natural System

Studies of the natural system at Yucca Mountain have been of unprecedented extent and thoroughness. Here, we will try to put the natural system characterization efforts in the perspective of USGS studies and interpretations.

For more than 120 years, the USGS has provided scientific support to help resolve the Nation's complex natural resource problems. The USGS began applying that expertise to the Yucca Mountain region several decades before Congress selected the site for study as a potential repository location. Major geological and hydrological studies in southern Nye County were conducted by the USGS in support of national defense programs at the Nevada Test Site.

After the selection of Yucca Mountain for site characterization, USGS scientists worked with academic, national laboratory, and contractor geologists and hydrologists to compile a comprehensive description of the proposed repository site and its vicinity. The work included surface mapping, detailed stratigraphic measurements, studies of numerous soil pits and trenches, logging of hundreds of drill holes, observations in more than 10 kilometers (6 miles) of underground excavations, geophysical surveys, geochemical analyses, hydrologic tests, and studies of past climate records. The USGS stands firmly behind the quality of work that its scientists produced in the site characterization effort. Whereas scientific investigations commonly lead to additional possibilities for further work, the USGS is confident that the thoroughness of the work performed to date is sufficient to support a decision to proceed to the next step of repository site recommendation. At this time (October 2001), analysis of the extensive data by USGS scientists has found no feature or characteristic of the site that would preclude its designation as a repository site.

SITE ATTRIBUTES

Any potential repository site has attributes that are favorable for the isolation of waste as well as unfavorable. As site characterization proceeds, these attributes are studied exhaustively and the potentially negative attributes receive particular scrutiny. Yucca Mountain has been studied in this way and a number of site attributes, both positive and negative, have been documented. These are summarized below along with an explanation of why the negative attributes do not preclude a site recommendation decision at this time.

Positive Attributes

National screening programs conducted in the 1980s and site characterization studies have revealed a number of positive attributes of the natural system with regard to the siting of a potential geologic repository at Yucca Mountain. The local geology at Yucca Mountain is uncomplicated. Beds or layers of volcanic rocks of relatively uniform thicknesses dip gently to the east and are offset small amounts by northwesterly and northerly trending faults. The three dimensional geological framework of the mountain is well established by mapping, drilling, and underground exploration. In addition, the Yucca Mountain site has been thoroughly investigated for economic deposits that would be attractive for commercial mining and for energy resources, but there is no indication of either.

The volcanic tuffs at Yucca Mountain are suitable for underground construction, as shown by the relative ease with which exploratory tunnels, drifts, and alcoves were excavated using tunnel boring machines and alpine miners. This feature is favorable both for worker safety during normal operations and for waste retrievability well into the future should that become necessary.

Yucca Mountain is located in an arid climate zone of the northern Mojave Desert and receives about 190 millimeters (7.5 inches) of precipitation per year. Potential evapotranspiration exceeds precipitation by about an order of magnitude. Consequently, net infiltration is very low, averaging about 5 millimeters (0.2 inches) per year above the potential repository area under

current climatic conditions. Because of the capillary barrier that surrounds underground openings in unsaturated rock, the percentage of net infiltration that can enter drifts of the potential repository as seepage is small. Furthermore, the interconnected fracture network within the potential repository host rock (Topopah Spring welded unit) will allow free drainage of water that might enter an emplacement drift, thereby inhibiting ponding of water. In addition, the interconnected fracture network of the Topopah Spring welded unit facilitates natural, passive ventilation of the repository. Such long-term passive ventilation of the repository would be beneficial because of the potentially large amounts of heat and water vapor that could be removed by this natural process.

A fundamental attribute of Yucca Mountain is its location above an unsaturated zone that is among the thickest (500 to 800 meters or 1600 to 2600 feet) in the United States. This allows a repository to be situated at a significant vertical distance below the land surface and above the regional water table. Such a location in the unsaturated zone ensures that a repository is extremely unlikely to be flooded by ground water. This conclusion is supported by geochemical and mineralogic studies that indicate that the water table has remained well below the repository horizon for millions of years. Another significant attribute of the Yucca Mountain unsaturated zone is that the rocks of the Calico Hills Formation beneath the repository site contain zeolites that can significantly retard the transport of certain radionuclides. Finally, Yucca Mountain is located in a closed desert basin with no discharge beyond the regional drainage system or to the sea.

Negative Attributes

The principal objective of a geologic repository is to securely isolate nuclear waste from the biosphere (the environment and its inhabitants) to the greatest extent possible. In the previous section, we discussed natural attributes of the Yucca Mountain site that are favorable with respect to this goal; many of them are also referred to as "natural barriers" in Department of Energy (DOE) literature.

The Yucca Mountain site also has some characteristics that potentially may degrade repository performance and that consequently deserve scrutiny. If the President eventually designates Yucca Mountain, these attributes may require additional study and monitoring. These include: (1) earthquakes; (2) potential volcanic activity; (3) the existence of a large aquifer of potable water at depth beneath the repository; (4) future climate change effects; and (5) the regional complexity of the hydrogeologic system. Without minimizing the importance of these attributes, the USGS believes that they are understood well enough with respect to the potential performance of a repository to support a decision to take the next step in repository development. Our reasons follow.

The occurrence of earthquakes gives rise to strong ground motion and to surface faulting that primarily affects surface facilities. Critical operational facilities in the preclosure period, such as the waste-handling complex, can be designed to withstand earthquake ground motions following state-of-the-art engineering practice as applied to critical facilities. Whereas the

engineering design is outside the scope of USGS studies, the probabilistic hazard analysis upon which designs will be based is supported by the USGS and follows internationally recognized state-of-the-art.

The potential for volcanic activity has been extensively studied using probabilistic hazard analysis. The USGS concurs with expert panels that the probability of a repository-piercing eruption, including surface eruptions, is very low (on the order of 1.6×10^{-8}/year, or odds of 16 in a billion per year). However, other scientists believe that the probability may be perhaps ten times higher. Although this topic continues to be discussed, the total range of current probability estimates remains very low.

The presence of a deep aquifer beneath the site is a primary reason for the two decades of efforts by scientists to characterize the geology, hydrology, geochemistry, and paleoclimate of the Yucca Mountain site. The aquifer is a valuable resource for this arid region. For reasons described in the final section of this paper, the USGS believes that the risk of possible contamination of ground water remains low. Nonetheless, this matter should continue to be evaluated and a monitoring program associated with repository construction should be designed with these concerns in mind.

A variety of paleontologic, geologic, and isotopic evidence indicates that the climate of the Yucca Mountain area changed cyclically in the past million years. During this time it varied from that of the present -- mean annual precipitation and temperature of about 190 millimeters (7.5 inches) and 19 degrees Celsius (67 degrees Fahrenheit) -- to a few extremely cold and wet periods that may have had more than double modern precipitation and perhaps more than 11 degrees Celsius (20 degrees Fahrenheit) colder temperature. However, during most of the past million years, the region is believed to have had intermediate climates. Predicting future climate at Yucca Mountain from the geologic records is uncertain, but limits observed during the past one million years suggest that the climate is likely to be intermediate between the present and the extreme climate states during the next 10,000 years. Thus, the climate of the Yucca Mountain region would at such times be semi-arid, rather than arid, as it is today.

The present-day regional hydrogeologic system is complicated, and is compounded by the inclusion of future climate change effects (for example, precipitation). Understanding this complex system is important in predicting repository performance. However, a substantial amount is known about the system, enough to understand the potential for the site's attributes to isolate waste.

CONTINUING STUDIES

The development of a high-level waste repository is a first-of-a-kind endeavor. The challenge to predict the performance of a proposed repository at Yucca Mountain has resulted in extensive local and regional studies as summarized above. Over time, site knowledge has increased dramatically and uncertainty in prediction of the performance of the natural system has been reduced. Nonetheless, the USGS also supports continuing study and monitoring efforts to

improve knowledge of the site, to further reduce uncertainty, to apply new earth science concepts as they develop, and to gather data to support refinements in repository plans.

B. Design and Engineering Considerations

COOL REPOSITORY

Engineered barriers can complement the natural barriers in isolating waste from the biosphere and can do much to offset uncertainties in characterizing the natural site conditions. One proposed engineering approach is to allow the rocks adjacent to the waste packages to exceed the boiling point of water, thus driving moisture away from the tunnels. The USGS supports a cooler operating regime (one in which the rock temperature never exceeds the boiling point of water) because of reduced impact on natural assets of the repository system and reduced uncertainties in predicting the repository system behavior. The USGS has consistently held this position for 23 years, since publication of USGS Circular 779, and continues to believe that the potential advantages of an above-boiling repository have not been sufficiently demonstrated to warrant changing our position.

VENTILATION

In keeping with the USGS belief that the repository host rock temperature is kept below boiling, we support the proposed practice of using a combination of forced and natural ventilation of the drifts for the time necessary to prevent the drift wall temperatures from ever exceeding the boiling point of water. A substantial added benefit of drift ventilation is the removal of a large volume of rock moisture from the repository environs. This water must be replaced by infiltration following the end of ventilation before seepage into the drifts could occur. Thus, conditions for possible radionuclide transport could be delayed by hundreds to thousands of years. Again, this is a long-standing USGS position, held for 18 years, since publication of USGS Circular 903.

RETRIEVABILITY AND MONITORING

DOE proposes in the Yucca Mountain Preliminary Site Suitability Evaluation that the repository may remain open for as much as 325 years and will be designed to include waste package retrieval capabilities prior to closure. One of the advantages of locating a repository in the unsaturated zone is that it remains more accessible (e.g., for retrieval of waste) than a repository below the water table. A repository above the water table does not need to incorporate backfill in the waste-disposal drifts and will not flood after closure. As a result, extending the preclosure period may be economically feasible (as shown by DOE's consideration of a preclosure period exceeding proposed regulatory minimums) and retrievability after closure remains a possibility. The USGS remains supportive of repository designs that facilitate retrievability, as pointed out in USGS Circular 903.

The USGS also supports design elements that incorporate the ability to monitor key attributes of the site, including moisture movement through the unsaturated zone, temperature, and water-table levels. A comprehensive monitoring plan is strongly endorsed by the USGS as a means to continuously evaluate the site prior to reaching a decision on closure. This will allow continuous validation and confidence building in the attributes of the natural system upon which the repository design is based. After waste emplacement, it is important to assure that the repository is functioning as expected and within accepted limits.

IV. RISK TO HUMANS AND THE ENVIRONMENT

The disposal of wastes produced by human activities has been an ongoing problem for societies throughout the world since the beginning of civilization. A new challenge arose following the Industrial Revolution with the need for industrial societies to dispose of increasing quantities of toxic solid and liquid chemical wastes. The problem of toxic-waste disposal acquired a new dimension with the advent of the nuclear age in 1945 and the subsequent need to dispose of accumulating quantities of long-lived radioactive wastes. The disposal of radioactive wastes requires that these materials be isolated from the biosphere for time periods necessary to protect the environment and to ensure human health and safety. The National Research Council, in a recent report ("Disposition of High-Level Waste and Spent Nuclear Fuel"), reiterated its belief, and that of all nations with nuclear power, that underground disposal of nuclear wastes in a geologic repository is the "only long-term solution available."

Radioactive-waste materials may reach the biosphere from a geologic repository by the mobilization and transport of radioactive substances by water moving through the repository system. Most proposed geologic repositories would be located below the water table where the wastes are in continuous contact with ground water. Yucca Mountain is an exception. Because of the thick unsaturated zone beneath this ridge, the waste can be emplaced several hundred meters (hundreds of feet) below the surface, yet also several hundred meters (hundreds of feet) above the water table. Because of the arid climate at Yucca Mountain and the hydrologic characteristics of the unsaturated rock mass in which the potential repository would be located, minimal quantities of ground water are expected to pass through the potential repository horizon under present-day conditions. Under expected future wetter climates, the natural attributes listed above in conjunction with the proposed engineered barriers should limit contact of waste with infiltrating water during the regulatory 10,000-year compliance period, and beyond.

The regulations that govern development of a potential Yucca Mountain repository require that the collective processes that may lead to release of radionuclides to the environment be evaluated using the Total System Performance Assessment (TSPA) methodology. TSPA is an internationally recognized tool not only for evaluating expected future repository-system performance but also for identifying additional data and information needs and for eliminating sites that may prove to be unsuitable for repository development. Although the USGS has not been involved directly in conducting the TSPA evaluations for the Yucca Mountain site, the earth-science investigations, data, and interpretations by the USGS have provided the fundamental scientific basis for these evaluations. The TSPA evaluations to date indicate that

the radioactivity released to the environment from Yucca Mountain is likely to meet regulatory limits. The USGS recognizes the benefits of the TSPA modeling technique as an important evaluation tool, but the limits of quantitative prediction as embodied in the TSPA over such long time periods need to be recognized.

Additional confidence in the site's long-term ability to isolate waste from the biosphere can be attained through the examination of natural analogues and through geochemical studies. Fossils and archaeological finds in caves and in human-made openings in rock comprise natural analogues for the possible fate of waste emplaced in the thick unsaturated zone beneath Yucca Mountain. Throughout the southwestern United States packrat middens, delicate fossils readily dissolved by water, are found in caves, rock shelters, and fissures. These middens are as much as 40,000 years old. Spirit Cave, Nevada, is famous for its 9,000-year-old mummies. Even in humid climates, caves contain fragile items such as ice-age paintings, some as much as 32,000 years old. These paintings have survived, in over 150 caves in the presently sub-humid to humid climates of southern France and northern Spain, presumably owing to the tendency of infiltrating water to move around openings within the unsaturated zone. Detailed study of calcite and opal deposits in cavities within the exploratory drifts in Yucca Mountain has shown unequivocally that the water table has been below the proposed repository horizon for millions of years. Additionally, these studies indicate that the climatic shifts recorded at the surface were greatly attenuated at the level of the proposed repository.

Recognizing that uncertainty in the future performance of the repository remains, and that continuing monitoring and scientific work will enhance understanding of critical processes, the USGS endorses national (National Academy of Sciences/National Research Council) and international (Nuclear Energy Agency) positions in favor of stepwise decisionmaking or phased development approaches. As stated by the Nuclear Energy Agency, a stepwise approach "leaves open the possibility of adaptation, in the light of scientific progress and social acceptability, over several decades, and does not exclude the possibility that other options could be developed at a later stage."